Report No: TSD/02 dated Dec-2005

TITLE:	MECHANISM AND ANALYSIS OF WEAR

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MECHANISM AND ANALYSIS OF WEAR

1.0 NTRODUCTION:

It has been accepted as a fact of life that heavy engineering plant & machinery during their operation undergo surface tearing or material displacement and results in a severe diminution in service performance. This phenomenon is called wear and can be described as, “the progressive removal of material from a surface stemming from relative movement at that surface.” In an operating environment, wear can be caused by a number of specific mechanisms. However, the practical situation is often more complicated due to the presence of several of them. Any change in the system like; material, stress, speed, temperature or other environmental conditions can have a significant effect on the type of wear or wear rate of a component.

Depending on the prevalent mechanism, wear can be classified into various categories.

2.0 TYPES OF WEAR:

2.1 Adhesive wear

It is the most common mechanism of wear, which occurs between two rubbing surfaces accounting 15-20% of industrial wear. If two apparently smooth surfaces are placed in contact and an attempt is made to slide one across the other, a frictional force acts between the two contacting surfaces to prevent the motion. On a microscopic scale, even a smooth surface consists of a series of jagged peaks and valleys. When such two surfaces are placed in contact and attempts are made to slide them one across the other, causes fracturing of the weakest point and allows sliding. The amount of wear during this displacement depends on various factors including the applied load, speed, temperature, true contact area and cleanliness of the rubbing surfaces.

The volume of wear is proportional to the load applied and distance traveled by the moving surfaces. The rate of wear is thus defined as,

$$\text{Rate of wear} = [(k * L * Y) / (A * t)] = k * P * V$$

Where,	L = Load	Y = Displacement	A = Contact area
	t = Time of contact	P = Pressure	V = Relative velocity

The constant, k is known as the wear factor, and is dependent upon the mechanical properties of the contacting materials. A lower yield point material gives rise to larger area of true contact area, thereby causing greater wear.

Lack of lubrication and in-sufficient surface finish can also promote a condition of wear called ‘scuffing’. This category of wear generally occurs inside the engine cylinder.

Typical surface hardening treatment like; nitriding, carburising, carbo-nitriding, cyaniding those changes the surface structure of the material to increase the yield point, widely used to improve the wear resistance of cast iron and steel components from adhesive wear.

2.2 Abrasive wear

When the erosion of metal surface takes place due to cutting or gouging action of hard particles, it is called abrasive wear. This type of wear accounts almost 50% of the industrial wear problems. Since the rate of wear depends on the relative hardness of the abrading and abraded material, the characteristics of each of them shall be suitably studied. The relative hardness of few common minerals and material phases are shown in Table-1.

Table-1: Hardness values of some abrasive & material phases

Mineral/ Material	Hardness, HV
Coal	32
Gypsum	36
Lime	110
Calcite	140
Fluorspar	140
Coke	200

Material phase	Hardness, HV
Ferrite	70-200
Pearlite	250-450
Austenite	170-350
Martensite	500-1010
Cementite	840-1100
Chromium carbide	1200-1800

Iron ore	470
Glass	500
Feldspar	700
Sinter	770
Quartz	900
Corundum	1800

Alumina	2000
Niobium carbide	2000
Tungsten carbide	2400
Silicon carbide	2600
Vanadium carbide	2800
Boron carbide	3700

Depending on the wear mechanism and prevailed condition of wear, it can be divided into three main types – a) Gouging abrasion, b) Low stress abrasion & c) High stress abrasion.

2.2.1 <u>Gouging abrasion</u> – This kind of abrasion is encountered during transportation or size reduction of large lumps of material and mainly encompasses a certain amount of impact and consequent plastic deformation of the material surface.

Such kind of wear is generally encountered in areas like; pulverizor mills, impact area of chutes, digger shovels, etc. In this kind of wear, impact resistance is also important. Thus, a work hardened surface with a toughened core like; austenitic manganese steel is often used for such applications.

2.2.2 <u>Low stress abrasion</u> – This type of wear results during sliding action of free-moving particles over a surface. The wear takes place due to scratching of the surface. In this kind of wear, impact resistance & toughness is not so important. Therefore, relatively brittle or hard wear resistant material is of preferred choice.

Low stress abrasion is encountered in chutes handling free flowing minerals. Alloy cast iron is generally recommended for such applications.

2.2.3 <u>High stress abrasion</u> – This type of abrasion occurs between two loaded surfaces. For example; rock drills, milling equipments, crushers, ball mills, etc. The wear surface suffers very high stress that causes the particles to penetrate the surface and also result in fracture of the brittle phases present in the matrix.

High yield strength material with an appropriate combination of hardness is generally preferred for such applications.

2.3 Erosion wear

This kind of wear is encountered when free-flowing solid particles or liquid droplets impinge on a surface. These particles or droplets are carried in a fluid stream of high velocities. The rate of erosion depends on the kinetic energy of the eroding particles and the way the dissipated particles impinge on the surface. The extent of damage is dependent on particle size, shape, concentration, velocity, angle of attack and most important is on material selection.

At relatively low angle of impingement (<30°), wear rate is critical on surface hardness like low stress abrasion. Hard alloyed cast iron, chrome irons are commonly used. However, when the impingement angles are large, resiliency is more important. For such cases, material having low elastic modulus like rubber becomes a better choice.

2.4 Cavitation wear

During transportation of a liquid, rapid changes of pressure cause formation of gas or vapour bubbles. When these bubbles collapse on a surface continually that may lead to a type of wear known as cavitation wear.

This type of wear is generally associated with pump impellers, ship propellers where a sudden change of direction of liquid flow is encountered. The relative resistance to cavitation of some commonly used materials is shown in the Table-2.

Table-2: Relative resistance to cavitation of some commonly used materials

Stellites	Maximum resistance
Nylon	
Ni-Al bronze	
Austenitic stainless steel	
Monel	
Mn-bronze	
Cast steel	
Bronze	

Cast iron	Minimum resistance

2.5 <u>Corrosive wear</u>

This type of wear is observed due to interaction of the wear surface and a corrosive environment. The wearing on the surface promotes continuous exposure of new surfaces, which is then exposed to further corrosive attack. Conversely, in some circumstances like adhesive wear process, presence of corrosion product like oxide film may drastically reduce the wear rate.

3.0 ANALYSES OF WEAR

Hardness is quite often used to judge the wear resistance criteria for hard-surfacing deposits & overlays. Though this holds good for some cases but significantly differ especially when the microstructures are different.

Carbon steel with 0.2% carbon in normalized condition consists of ferrite-pearlite structure (figure-1) with a hardness of ~160 BHN. After water quenching the same steel from 900°C, the structure consists of martensite (figure-2) having hardness of approximately 400 BHN. The martensitic structure being harder will have a better resistance to low stress scratching abrasion than the former. However, the result will be opposite for high stress grinding abrasion.

The presence of hard (~1200 BHN) iron carbide (Fe_3C) in the alternate lamellae of ferrite (figure-3) will resist the grinding action and will have a better resistance than the martensitic structure. If some fine abrasive particles are present between the grinding wheel & steel, ferrites in between the lamellae will wear out fast and iron carbides will fracture having lack of support. Therefore, the wear pattern for the similar structure may change if the abrasive media is changed.

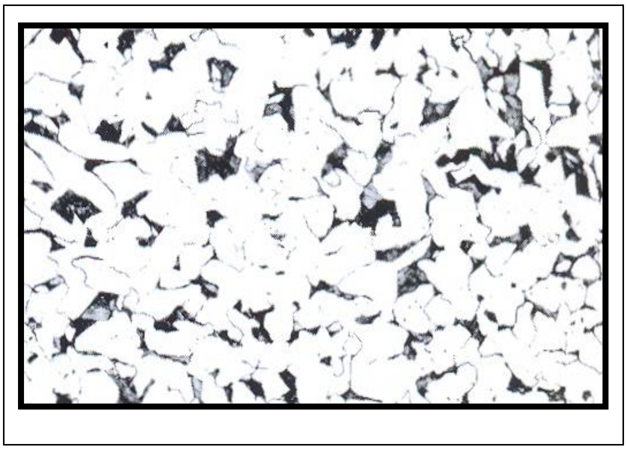

Figure-1: Microstructure of 0.2% C steel in normalized condition, 200X

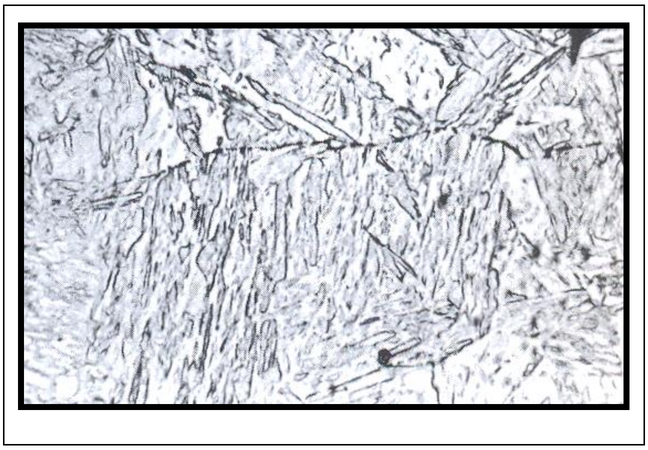

Figure-2: Microstructure of 0.2% C steel in water quenched condition, 200X

A network of carbides and a matrix of hard alloy martensite is therefore a more desired structure (figure-4) to provide both low stress scratching & high stress grinding abrasion.

Toughness is the property that combines an optimum of both strength & ductility. It is inversely related to hardness i.e., for a high hardness hard-surfacing deposit has poor/ less resistance to impact. Often, a combination is needed together, in such instances a compromise has to be made between the two for the optimum.

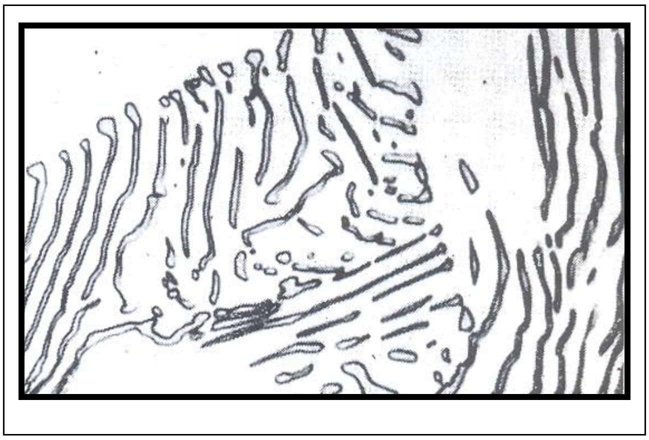

Figure-3: Microstructure of 0.2% C steel showing ferrite-carbide lamellae, 800X

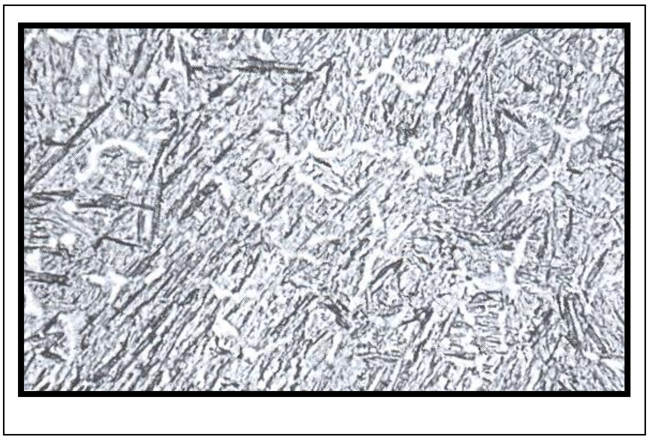

Figure-4: Microstructure of hard-surfacing alloy showing carbides in a martensitic matrix, 200X

For applications involving stone crushers, points & crossings of railway tracks, the properties like; toughness & resistance to galling is important. A brittle material will immediately be chipped off.

A combination of impact and abrasion works together in a blast furnace charging bell. For such application, hard-facing alloy should be tough enough to withstand the impact but also should have good abrasion resistance. Maximum abrasion resistance is obtained by large volume fraction of carbides in a high strength austenitic matrix (figure-5).

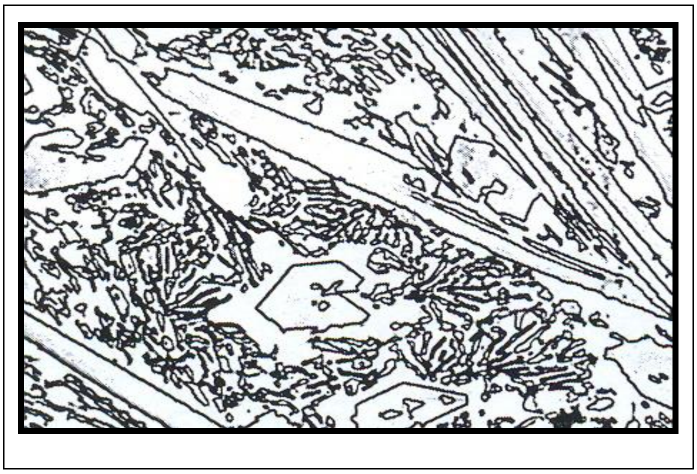

Figure-5: Microstructure of carbide distribution in a high chromium austenitic iron matrix, 200X

For elevated temperature applications, retention of hardness at higher temperature as well as good oxidation resistance property is essential.

Considering above factors, the suitable alloys are selected for the necessary application. Typical applications related to various abrasion & impact resistances of deposits are summarized in Table-3.

Table-3: Service conditions and typical applications

Abrasion resistance	Impact resistance	Typical applications
Low	High	Metal-to-metal wear like; rails, shaft, axles, Track rollers & links, dog clutches, etc.
Medium	Medium	Metal cutting & forming tool like; shear blades.
High	Low	Excavator bucket & teeth, bulldozer blades, plough shares, agricultural equipments, etc.

In a fusion welding process the weldment consists of microstructurally distinct regions. They are; mixed zone (weld metal), unmixed zone (base metal), partially melted zone and heat-affected zone, as shown schematically in Figure-6.

The mixed zone, also known as the composite zone and fusion zone, is the fused region in a weldment where the filler material has been diluted with material from the base metal. Composition of the zone depends on the composition of the filler metal &

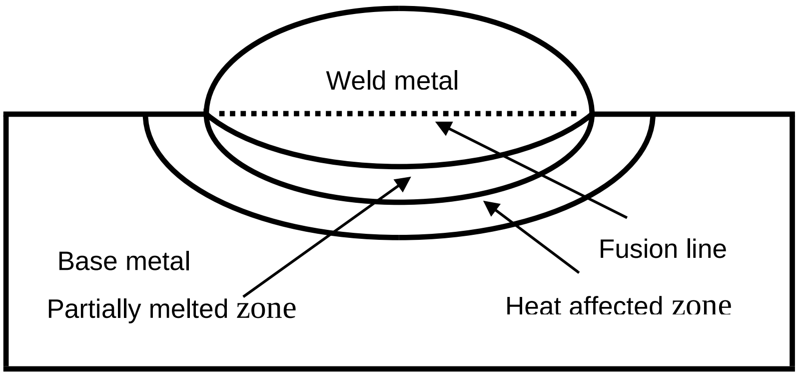

Figure-6: Schematic sketch of a weldment

the base metal. The extent of dilution is a function of heat input, joint geometry, welding position and process. The degree of dilution for various welding processes is shown in Table-4.

Table-4: Dilution levels for various welding processes

Process	Dilution, %
Spray fusion	Nil
Plasma spraying	Nil
Oxyacetylene gas welding	Less than 5
Manual metal arc welding	10-30
Flux-cored arc welding	10-30
Submerged-arc welding	10-40

For a highly alloyed hard-surfacing deposit, it is always desirable to use a low dilution process. But, this is not always possible considering the economics of the process as the low dilution processes generally have lower deposition rate. However, if large areas are to be hard-surfaced, overlap of adjacent beads can considerably reduce the dilution (figure-7). A more overlapping welding technique is generally followed for a high deposition rate process.

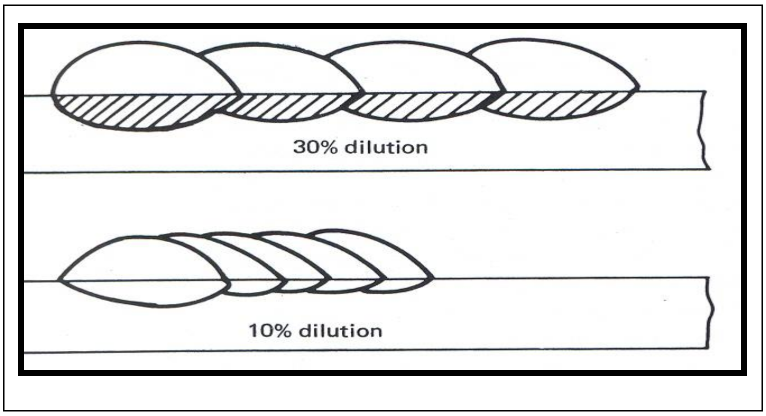

Figure-7: Effect of welding technique on dilution

4.0 SUMMARY

1. Among the various wear mechanisms prevalent in the industries, abrasive wear shares the maximum (>50%). The other major wear processes encountered are metal-to-metal wear, impact wear and wear due to corrosive attacks.
2. Proper understanding of the mechanism of wear is essential to obtain a successful hard-facing solution.
3. Finally, irrespective of the selection of material, the proper deposition ensures the expected performance.

Acknowledgements

The authors gratefully acknowledge the Management of D & H Secheron, Indore to encourage & publish this work.